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THE UNIVERSITY OF MICHIGAN
SPACE PHYSICS RESEARCH LABORATORY
COLLEGE OF ENGINEERING
DEPARTMENT OF ATMOSPHERIC, OCEANIC AND SPACE SCIENCES

Memo:

To:

Subject: Continuation of funding for grant NAG1-1315 entitled "Mesospheric and lower thermospheric winds, temperatures densities and volume emission rates: provision of a multi-station, long term, ground based data set in support of the UARS mission".

From: Prof. T. L. Killeen, Principal Investigator.

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1. INTRODUCTION

This memo has been written to report on the progress made under grant NAG1-1315 and to request a continuation of funding for this work. Our proposal involved a plan to utilize an existing ground-based chain of optical and radar facilities to assemble a comprehensive, long-term, multi-station base of upper-mesospheric and lower thermospheric measurements of neutral winds, temperatures and volume emission rates that can be used to make comparisons with data from the HRDI and WINDII instruments that are flying aboard the UARS spacecraft. The ground-based, optical data were to be obtained on a routine basis from five geographically separated observatories at: 1) Thule, Greenland; 2) Søndrestrøm, Greenland; 3) Watson Lake, Yukon (replacing Calgary, Alberta); 4) Ann Arbor, Michigan; and 5) Maynooth, Eire. Several different optical instruments are present at these sites: the total array of instruments is comprised of five Fabry-Perot interferometers, two half meter Ebert-Fastie spectrometers, one all-sky CCD imager, and a near infra-red Michelson Fourier transform spectrometer. In addition to these optical instruments, data were to be obtained from the incoherent scatter radar at Søndrestrøm, Greenland. These radar measurements are comprised of neutral winds, temperatures and densities from altitudes between ~70 - 120 km. The optical measurements are obtained locally from specific altitudes depending on the emission line studied. For example, red line optical data come from about 220 km.

In this report we summarize the progress made in obtaining these data and relate it to the specific tasks outlined in the original grant application. These tasks are discussed in the next section. Progress towards their completion is discussed in section 3, while future plans and summary are described in section 4.

(NASA-CR-195147) MESOSPHERIC AND LOWER THERMOSPHERIC WINDS, TEMPERATURES DENSITIES, AND VOLUME EMISSION RATES Annual Report (Michigan Univ.) 23 p

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2. WORK REQUIRED UNDER GRANT

In general the work proposed under this grant was: 1) to validate wind, temperature and species density measurements from the HRDI and WINDII instruments for selected overflights of ground stations; 2) to provide long term complementary data of mesopause wind, temperature and species densities for CDHF; and 3) to provide complementary measurements of geophysical parameters not observed by UARS instruments (e.g., OH imaging). The main purpose of this program is to obtain data from the ground stations mentioned above and to provide these data in a timely fashion to the UARS data system. Additionally, the investigator team were to support UARS team meetings and to perform interpretative tasks to optimize the scientific return from the proposed correlative program. Several specific tasks were proposed under this broad umbrella. These tasks were:

1) Modify the existing operational strategy of the SPRL optical network to emphasize mesopause and lower thermospheric measurements in coordination with UARS.

2) Perform a long-term series of measurements of upper mesospheric and lower thermospheric parameters from the various observatories.

3) Support individual campaign efforts involving overflights of UARS.

4) Provide a systematic and documented data product containing the measurements discussed earlier to the UARS data system.

5) Perform data analysis and data interpretation tasks in conjunction with UARS team members and also provide scientific support for UARS team meetings.

6) Perform validations tests for the HRDI and WINDII instruments flying on board the UARS satellite.

7) Provide important complementary information that relates to the PEM, SOLSTICE and SUSIM instruments.

In the next section we describe the progress that we have made in doing these various tasks.

3. Progress Towards Completion of These Tasks.

In the previous section we stated that the primary purpose of the current proposal, as well as the extension to the current proposal, is to provide data to the UARS system from the ground stations discussed earlier. We have detailed our efforts to meet this goal in two ways: first by establishing the format required for the data; and second by collecting the data required from the individual stations.

Table 1 shows a monthly summary of data collection from the five observatories. The annotation on the left side gives the station and the data type. For instance, "FPI red" represents data from the $O(^1D)$ emission. The peak of this emission is typically around 220 km and thus represents thermospheric data. The annotation "FPI green" corresponds to the green line $O(^1S)$ emission with peak altitudes of around 97 km, while "FPI OH" is a hydroxyl emission which peaks at about 87 km. Additionally "MI OH" denotes Fourier transform spectrometer measurements of the hydroxyl rotational temperature and emission brightness. ISR refers to the incoherent scatter radar experiment at Søndre Strømfjord. ASI refers to the all sky imager at Peach Mountain. The dots in the monthly boxes refer to months for which we have the corresponding raw data. At this time, all available FPI Søndre Strømfjord geophysical data have been submitted to the CDHF data base.

Several complications affect the data availability within the data collection windows described by Table 1. The optical data are limited by Rayleigh scattering of sunlight and by the cloud cover over the site. In the CDHF data base, days when the data are unreliable because of cloud cover are indicated by the cloud cover record that we are also submitting to the UARS data system. Table 2 describes the process that we take between data acquisition and data submission. All optical raw data is initially archived at SPRL, then corrected for instrumental effects and reduced to geophysical parameters, and then submitted into an in house data base. For the current grant, we have employed several individuals to communicate with CDHF (via Warren Hypes) in order to reprogram our data formatting system to employ the CDHF format. The software for this transformation is now available to us permitting us to reformat for CDHF. The final step in our submission is to transmit the data to our liaison, Paul Hays, for quality control and final transmission to CDHF.

We have processed some incoherent scatter radar data from Søndre Strømfjord. These data were presented at the Chapman Conference on The Upper Mesosphere and Lower Thermosphere in November 1992. Further processing is needed to put these data in a format suitable for the UARS data base. This processing is continuing, so that final submission should occur soon after the data from Watson Lake and Maynooth are entered into the data base.

The preceding paragraphs described our general progress in preparing data for the UARS data base. On page 2 we outlined the 7 specific tasks that we are expected to complete under the auspices of grant NAG1-1315. The following bullets describe our progress in each of these specific tasks.

1) We have upgraded the all sky camera system to allow us to observe gravity wave features in the OH nightglow. At present, we are considering strategies for processing these data in a way that is consistent with the structure of the UARS data base. As well as this instrument upgrade, we have also altered our operating strategy for our other instruments. Previously, operating modes have been selected on a "pseudo-campaign" basis, where the mode of operation was determined by the specific experiment with emphasis being placed on the thermospheric red line measurements. Obviously, such a tactic is not suitable for long term comparisons with satellite data that are mainly measured near the mesopause and below, so we now operate our instruments (Søndre Strømfjord and Ann Arbor at present as these are the key stations matching the two side looking directions of the UARS satellite) in either their green line or OH modes on a regular basis matching daily filter selection forecasts from the WINDII team. In addition, specific radar runs have been made at Søndre Strømfjord to obtain upper mesospheric and lower thermospheric results.

2) We are continuing our long term measurements at the various sites discussed earlier. FPI measurements in the mesopause region are proceeding at Ann Arbor. Dr. Niciejewski has and will continue to travel to Thule Air Base, Søndre Strømfjord, and Watson Lake to initiate measurements at the appropriate times (September of each year) and to return data sets and terminate operations when appropriate (usually in April of each year). The all sky camera is currently acquiring data at Ann Arbor whose station we can service daily, while the Maynooth station continues operation under the management of Prof. Mulligan.

3) In addition to these long term monitoring efforts, we have supported a specific campaign involving the UARS measurements. The 1992 Noctilucent Cloud sounding rocket campaign compared overflights of UARS with rocket probes. We supported this effort with our FPI and a Fourier transform spectrometer at Watson Lake. Personnel from our group traveled to Watson Lake to operate these instruments during this campaign. Operations with the incoherent scatter radar in January, 1993, were performed at the same time as northerly pointed HRDI transits. We have added remote real time monitoring hardware and software to permit modification of operating parameters at our optical sites in Søndre Strømfjord and Watson Lake to assist in last minute fine tuning of our observing strategy to match changes in filter choices for WINDII.

4) We have submitted all available Søndre Strømfjord FPI geophysical data, consisting of both green and red line measurements of winds and temperatures to the UARS CDHF data system. In addition, we have collected and analyzed FPI red line measurements from Watson Lake station. These Watson Lake geophysical data (winds and temperatures) are ready for submission via our liaison. Prof. Mulligan has provided us with OH rotational temperature and brightness measurements from the Maynooth Fourier transform spectrometer. Currently, these Maynooth measurements and our Ann Arbor and Watson Lake Fourier transform spectrometer data sets are being prepared for submission to the UARS data system, requiring the modification of the reformatting software that we have for our FPI measurements. This work is in progress.

5) We have been working with the HRDI and WINDII teams to make correlative comparisons between these satellite-derived data sets and our ground-based data. Progress has been made and will continue to be made as more satellite data are processed. Figure 1 displays one such comparison. Here, geophysical data measured by the Peach Mountain FPI operating in green line mode is shown in various time series including meridional wind (top left) and zonal wind (top right). During this period, the WINDII instrument was also operating in green line mode and made measurements within 500 km ground range distance from Peach Mountain. The reduced WINDII data indicate the following: at 0506 UT, a meridional wind of 52 m/sec and a zonal wind of -27 m/sec; at 0507 UT, a meridional wind of 29 m/sec, and a zonal wind of -56 m/sec. These values are near the values measured from the ground. In addition to these direct contacts with the individual instrument teams, we have participated in the general activities of the whole UARS team.

Figure 2 and Table 3 summarize semi-diurnal tidal measurements with the Peach Mountain FPI operating in OH mode. In Figure 2, hourly binned averaged winds are shown for three seasons: spring 92, fall 90, and winter 91. These data were then curve fitted with a mean wind plus a semi-diurnal tidal contribution leading to the phase and amplitude data displayed in Table 3.

Similar summaries for Thule Air Base and Søndre Strømfjord green line data are shown in the following displays. Figure 3 and Table 4 describe fits to Thule Air Base data for two different winter seasons for both the meridional and the zonal wind components. Figure 4 and Table 5 describe similar results for Søndre Strømfjord for the winter seasons. Finally, Figure 5 displays hourly averaged horizontal neutral wind vectors for Thule Air Base (inner ring) and Søndre Strømfjord (outer ring) on a local solar time-latitude polar dial plot. This work is currently in progress. Figure 6 displays incoherent scatter radar geophysical data for the LTCS VII campaign of 3/30 - 4/2, 1992. These data are currently being reduced for additional time and altitude values.

Several investigators from our group attended the UARS Dynamics Meeting in Ann Arbor, Michigan in October, 1992. Dr. Killeen gave two talks during this meeting: one on thermospheric dynamics and the other on ground-based measurements. We made our ground-based measurements of mesospheric winds and Doppler temperatures available during this meeting. Additionally, we offered OH rotational temperature measurements from the Maynooth station to the HRDI and WINDII groups at this time. We also participated in the UARS Dynamics meeting at York University in Toronto, Ontario, during April, 1993. Dr. Niciejewski reported on our progress with submissions to the CDHF data base up to that date and worked with the WINDII team in isolating several coordinated measurements between WINDII and Søndre Strømfjord, and WINDII and Ann Arbor.

6) As stated earlier, we are in close contact with the HRDI and WINDII groups to ensure that correlative data comparisons are made when overlaps of data coverage between the satellite measurements and our ground-based measurements occur. This will provide validations and baselines for the satellite-derived wind and temperature measurements. This is an ongoing effort and it is necessary to continue this program throughout the entire lifetime of the WINDII experiment to assist in characterizing any long term instrumental drifts of the satellite instrument.

7) We will be able to provide complementary information for the PEM, SOLSTICE and SUSIM instruments once the validation work described in bullet 6 is completed.

In addition to this work directly relating to the tasks proposed under grant NAG1-1315, we have also participated with the HRDI and WINDII groups in the Chapman Conference on the Upper Mesosphere and Lower Thermosphere that was organized by Drs. Johnson and Killeen. Dr. Johnson presented a poster paper to this meeting on the Søndre Strømfjord data that was measured during the UARS overpasses, while Dr. Killeen presented an overview of our various stations.

4. Future Plans and Summary

An exciting opportunity exists today that was unavailable during the formulation of the original proposal. Several new additions have been made to the Søndre Strømfjord aeronomical facility that would provide an additional benefit for UARS validation and permit new correlative science to proceed. In particular, the incoherent scatter radar has very recently been upgraded to permit an ST radar capability providing neutral wind measurements for the troposphere and the stratosphere. These measurements are assisted by twice daily radiosonde balloon launches from a nearby coastal location at Egedesminde. The radiosonde is capable of measuring humidity, pressure, temperature, and wind as a function of altitude from ground to the stratosphere. A major addition to the facilities instrumental complement has been the successful integration of a LIDAR system under the direction of Dr. Jeff Thayer of SRI International. The LIDAR is capable of monitoring temperature within the stratosphere. Table 6 summarizes the new capabilities. Our group has an excellent working relationship with SRI International and would be able to petition SRI to concurrently operate the ISR in ST mode and the LIDAR on a once per two-month basis, each experiment lasting for a 24 hour duration. The go/no go decision would be made on the basis of a nearby UARS transit as well as cloud cover considerations by the Søndre Strømfjord site crew. The data sets would be reduced by SRI and then transmitted to us for integration into the CDHF data base on a timely basis. These new data would provide additional validation measurements currently unavailable to the community.

Considerable progress has been made on the primary tasks described in our original proposal: submitting data into the UARS data system, assisting HRDI and WINDII calibrations, participating in UARS meetings, and providing additional scientific support to the UARS mission. At present, we are continuing to collect and analyze data from the various instruments that exist at five different ground stations, and we are preparing these data for submission into the UARS data base. To develop this work further, we request a continuation of funding for grant NAG1-1315.

TABLES

TABLE 1. Tabular display of data sets available for the UARS Correlative Measurement Investigation. The station name and instrumental mode are shown on the left side. Entries in any box indicate there are data sets available for that month for UARS comparisons.

TABLE 2.Summary of data base products available for our suite of stations and instruments.

TABLE 3. FPI mean wind and semidiurnal oscillation amplitudes and phases for Ann Arbor for the several observing periods. Comparison is made with Forbes model output at the same latitude.

TABLE 4. FPI mean wind, diurnal, and semidiurnal oscillation amplitudes and phases for Thule Air Base for the winter period. Comparison is made with Forbes model output at the same latitude.

TABLE 5. FPI mean wind and 12-hr oscillation amplitude and phase at Søndre Strømfjord for the winter period. Comparisons are made with radar data from Søndre Strømfjord and Chatanika and with the Forbes model for March and September for the same latitude.

TABLE 6. A description of new capabilities that are now available at Søndre Strømfjord.

Stat. / Inst.	1991	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Søndre													
FPI red										•	•	•	•
FPI green										•	•	•	•
ISR											•		•
W. Lake													
FPI red												•	•
MI OH													
Maynooth													
MI OH											•	•	•
Peach Mt.													
FPI red													•
FPI green													•
FPI OH													•
MI OH													
ASI OH													
Ann Arbor													
MI OH													
UARS													
north											*		*
south												*	

TABLE 1

Stat. / Inst.		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	1992												
Søndre													
FPI red		•	•	•	•								
FPI green		•	•	•	•								
ISR			•		•		•		•		•		•
W. Lake													
FPI red		•	•	•	•							•	•
MI OH							•	•	•				
Maynooth													
MI OH		•	•	•	•	•							
Peach Mt.													
FPI red		•	•										
FPI green		•	•	•			•		•	•			
FPI OH		•	•	•	•	•	•	•	•	•			
MI OH			•	•	•	•							
ASI OH								•	•	•	•	•	•
Ann Arbor													
MI OH													•
UARS													
north		*	*	*		*		*	*		*		*
south		*	*		*		*	*	*	*		*	

Stat. / Inst.	1993	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Søndre													
FPI red		•	•	•	•							•	•
FPI green		•	•	•	•							•	•
ISR									•		•		•
W. Lake													
FPI red		•	•	•	•					•	•	•	•
MI OH													
Maynooth													
MI OH													
Peach Mt.													
FPI red													
FPI green		•	•	•	•	•	•	•	•	•	•	•	•
FPI OH		•	•	•	•	•	•	•	•	•	•	•	•
MI OH													
ASI OH		•	•	•	•	•	•	•	•	•	•	•	•
Ann Arbor													
MI OH		•	•	•	•	•	•	•	•	•	•	•	•
UARS													
north		*	*	*		*							
south		*	*	*	*								

DATA BASE PRODUCTS

1) Raw data

- FPI acquires fringes at Thule Air Base, Watson Lake, Søndre Strømfjord
- FPI acquires images at Peach Mt.
- Fourier transform spectrometer acquires spectra at Maynooth and Peach Mt.
- all sky camera acquires images at Peach Mt.
- ISR at Søndre Strømfjord acquires echoes

2) Reduced data

- FPI raw data are reduced to winds, temperatures, and columnar emission rates
- spectra are reduced to temperatures and columnar emission rates
- radar data are reduced to winds and temperatures

3) in house database

- daily geophysical data sets are concatenated into larger monthly or seasonal files
- cloud cover records are added to the data base, supplied by local meteorological stations

4) CDHF database

- the in house database is transformed into the CDHF format; code is currently available to perform this transformation for FPI data
- the transformed database is transmitted to our liaison for quality checking and final submission into the UARS CDHF database

• CDHF database submissions

- submitted all 1991/92 Søndre Strømfjord FPI geophysical data
- *in house* data base contains Watson Lake 91/92 FPI and Maynooth '92 MI geophysical data: requires us to reformat prior to submitting to Paul Cobbs
- *reduced* data base contains Peach Mt. 91/92 FPI and '92 MI geophysical data, Watson Lake '92 MI geophysical data, some Søndre Strømfjord ISR geophysical data: requires us to concatenate and then to transfer to our in house data base computer
- *raw* data base contains 92/93 Søndre Strømfjord FPI fringes, 92/93 Watson Lake FPI fringes, Peach Mt. '93 FPI images, Ann Arbor '93 MI spectra: requires data reduction
- principal investigators have Maynooth '93 MI, and most Søndre Strømfjord ISR data

TABLE 2

	FPI (Ann Arbor)				Forbes and Vial (89)		
	Mean (m/s)	12hr Amp. (m/s)	Phase (hr)	Day #	Month	12hr Amp. (m/s)	Phase (hr)
Meridional							
92 Spring	-2.8 ± 0.3	9.4 ± 0.4	5.6 ± 0.1		March	5.1	9.5
90 Fall	1.3 ± 0.7	24 ± 0.9	4.4 ± 0.1		September	4.0	5.0
91 Winter	-1.3 ± 0.9	19 ± 1.2	7.9 ± 0.2		January	4.8	6.6
					December	1.8	5.3
Zonal							
92 Spring	-2.6 ± 0.3	6.1 ± 0.4	9.1 ± 0.1		March	5.5	12.4
90 Fall	6.0 ± 0.7	32 ± 1.1	7.4 ± 0.1		September	4.4	8.0
91 Winter	25 ± 1.0	18 ± 1.6	9.6 ± 0.1		January	5.3	10.3
					December	1.5	10.1

TABLE 3

	Mean (m/s)	Amplitude (m/s)		Phase (hr)		# of days
		24 hr	12hr	24 hr	12 hr	
Meridional						
88/89 WINT.	7.7 ± 0.4	22.2 ± 0.7	5.5 ± 0.6	13.5 ± 0.1	3.3 ± 0.2	78
90/91 WINT.	9.1 ± 0.9	22.6 ± 1.4	18.3 ± 1.2	13.0 ± 0.2	3.5 ± 1.1	47
Forbes, Vial Model		2.9	15.1	11.9	5.8	Dec.
Zonal						
88 WINT.	7.4 ± 0.4	17.4 ± 0.6	3.1 ± 0.6	19.2 ± 0.2	7.6 ± 0.4	78
90 WINT.	7.3 ± 1.0	28.3 ± 1.2	18.9 ± 1.2	17.8 ± 0.2	5.7 ± 0.1	47
Forbes, Vial Model		2.1	16.0	18.3	8.8	Dec.

TABLE 4

	Meridional Winds			Zonal Winds			# of days
Winter	Mean (m/s)	12hr Amp. (m/s)	Phase (hr)	Mean (m/s)	12hr Amp. (m/s)	Phase (hr)	
Søndrestrøm FPI							
89/90 Wint.	-29.7 ± 0.6	24.4 ± 0.8	6.6 ± 0.1	1.4 ± 0.6	12.8 ± 0.8	10.4 ± 0.1	46
90/91 Wint.	-14.5 ± 0.6	17.4 ± 0.8	6.2 ± 0.1	0.5 ± 0.6	11.8 ± 0.8	9.1 ± 0.1	52
91/92 Wint.	-19.1 ± 0.6	22.0 ± 0.9	17.3 ± 0.1	-1.0 ± 0.6	14.2 ± 0.9	8.7 ± 0.1	43
Søndrestrøm radar	13.0 ± 4.0	38.0 ± 6.0	14.0 ± 0.3	-6 ± 7.5	35.0 ± 10	15.7 ± 0.5	
Chatanika radar	4.0 ± 7.0	12.0 ± 10	14.7 ± 1.4	20 ± 7.0	13.0 ± 9.0	7.6 ± 1.4	
Forbes,Vial Model		19.6	17.7		20.1	8.8	Dec.

TABLE 5

Table VI

New capabilities for Søndre Strømfjord

Instrument	Parameter	Altitude range	Comments
ST radar mode	neutral winds	5-20 km	
radiosonde	humidity pressure temperature wind	0-30 km " " "	two launches/day from Egedesminde
LIDAR	temperature	30-60 km	

TABLE 6

FIGURES

FIGURE 1. An example of a coordinated measurement sequence as observed by the green line mode Ann Arbor FPI for September 6, 1992. Here, the data for each time series are shown with vertical error bars. During this period, the WINDII instrument was also operating in green line mode and made measurements within 500 km ground range distance from Peach Mountain. The reduced WINDII data indicate the following: at 0506 UT, a meridional wind of 52 m/sec and a zonal wind of -27 m/sec; at 0507 UT, a meridional wind of 29 m/sec, and a zonal wind of -56 m/sec.

FIGURE 2. Zonal and meridional winds at Ann Arbor measured with the OH FPI mode. The observed, one hour averaged binned data are shown with vertical error bars, while a fit using the mean and the semidiurnal wind is shown with the solid line.

FIGURE 3. Zonal and meridional winds at Thule Air Base as a function of time for the winter period. The data have been averaged in one hour bins and a weighted mean calculated for each bin. Error bars represent the uncertainty of the mean. Superimposed on the data are the diurnal and semidiurnal fits (solid curve) to the data and model results (dashed line) for the semidiurnal oscillation.

FIGURE 4. Same as Figure 3, but for Søndre Strømfjord data. Superimposed on the data in the semidiurnal fit to the data and model results.

FIGURE 5. Horizontal neutral wind vectors measured above Greenland during the 1990/91 winter observing season displayed on a local solar time/latitude polar dial plot. Here, the inner ring of wind vectors corresponds to Thule Air Base, and the outer ring of wind vectors corresponds to Søndre Strømfjord. The magnitude of the neutral wind should be scaled with the vector at bottom right.

FIGURE 6. Zonal and meridional neutral winds and ion temperature determined from Søndre Strømfjord measurements obtained with the new system on 2 April, 1992 during the LTCS-7 experiment. In order to separate the curves in these panels, 200*(altitude-105)/3 m/s or 200*(altitude-105)/3 K have been added to the data for each altitude above 105 km.

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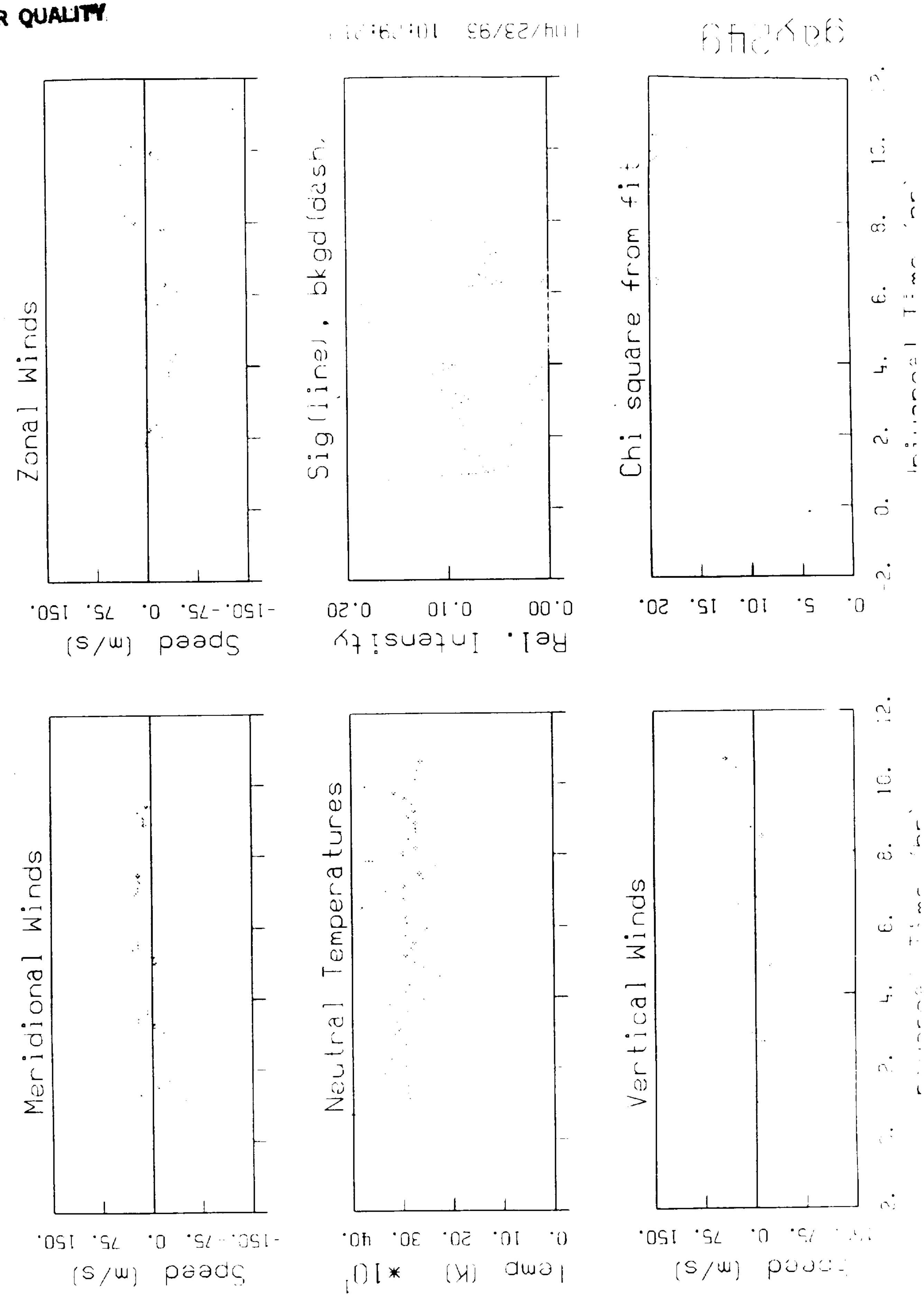


FIGURE 1

Ann Arbor

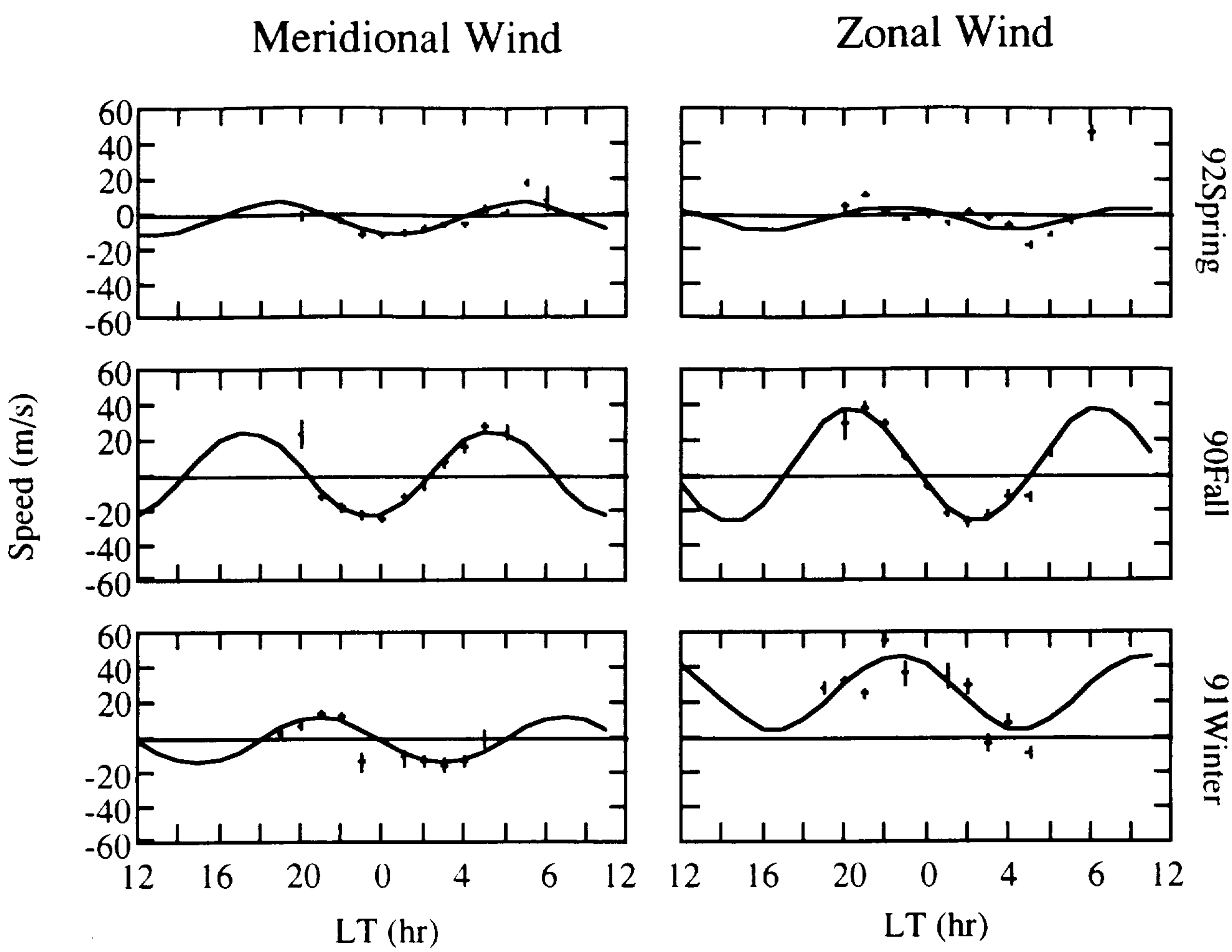
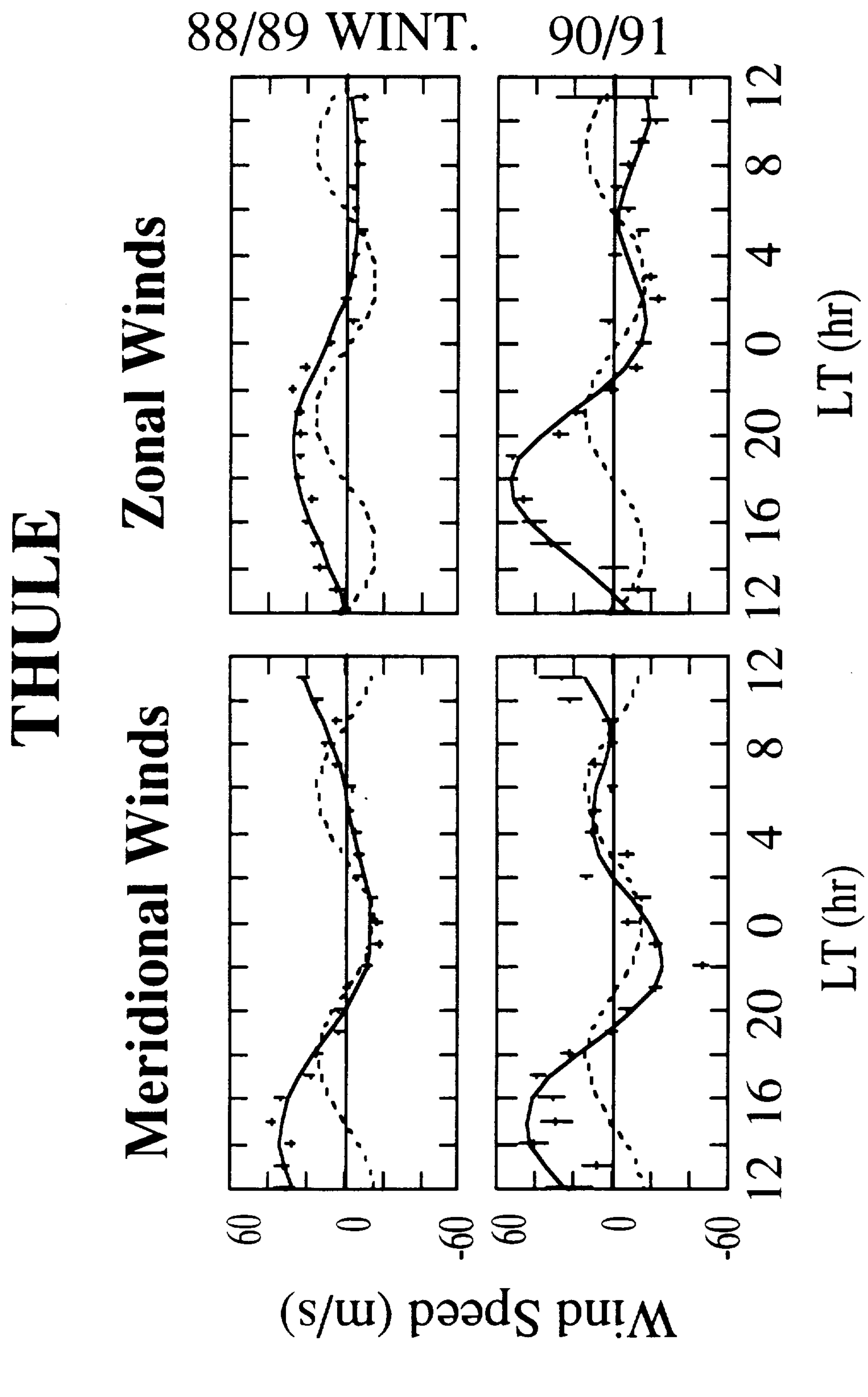
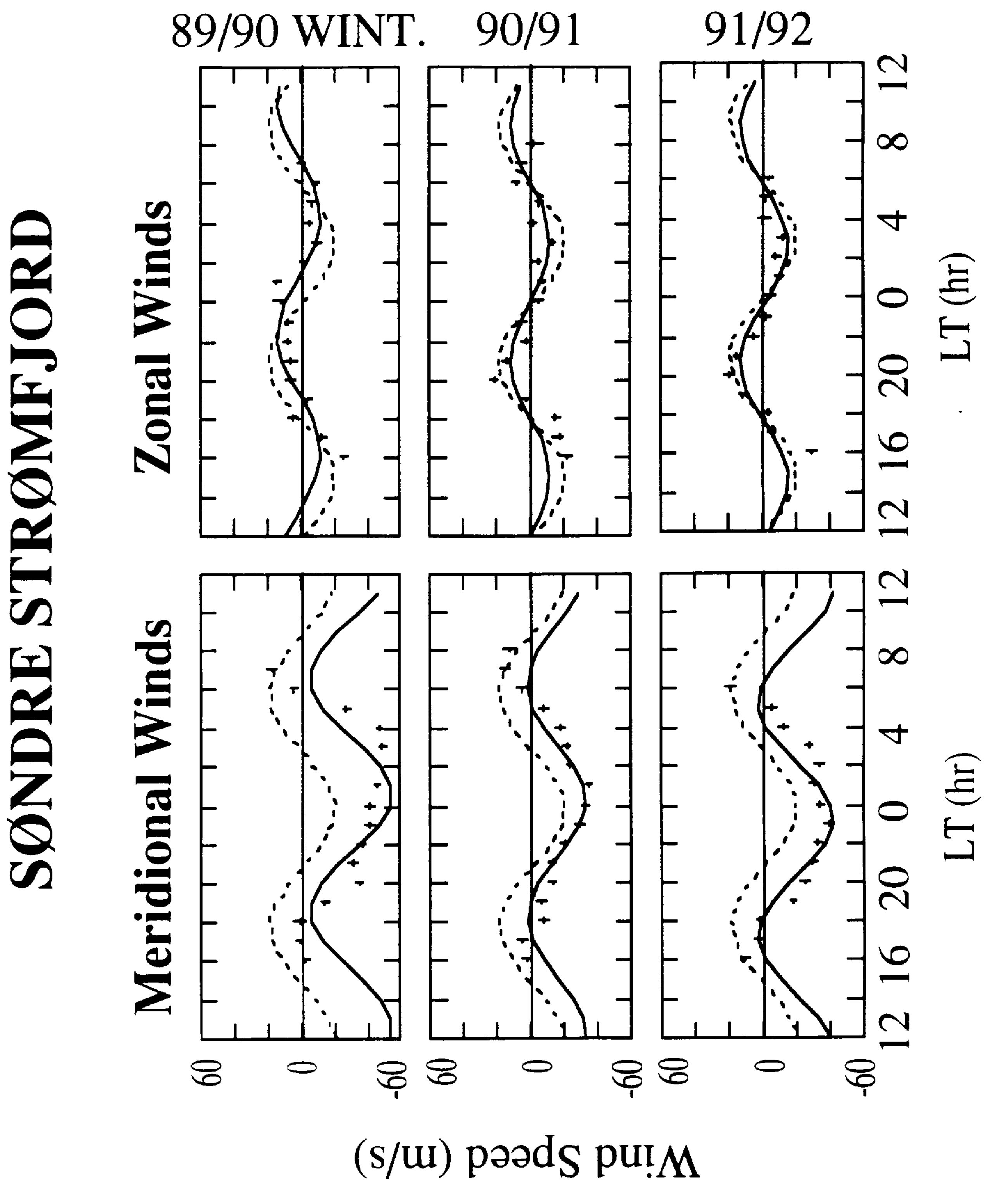


FIGURE 2



THULE
Meridional Winds
Zonal Winds
88/89 WINT.
90/91
Wind Speed (m/s)
60
0
-60
12 16 20 0 4 8 12
LT (hr)

FIGURE 3



SØNDRE STRØMFJORD
Meridional Winds
Zonal Winds
89/90 WINT.
90/91
91/92
Wind Speed (m/s)
60
0
-60
12
16
20
0
4
8
LT (hr)

FIGURE 4

1990/91 Winter

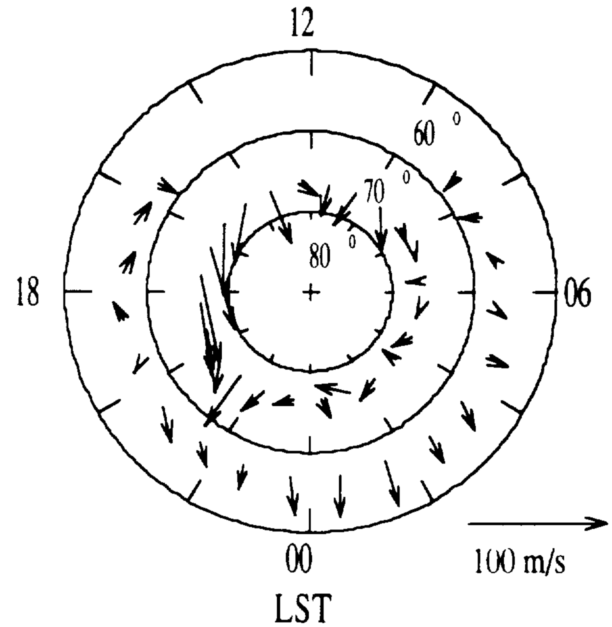


Fig. 5

FIGURE 5

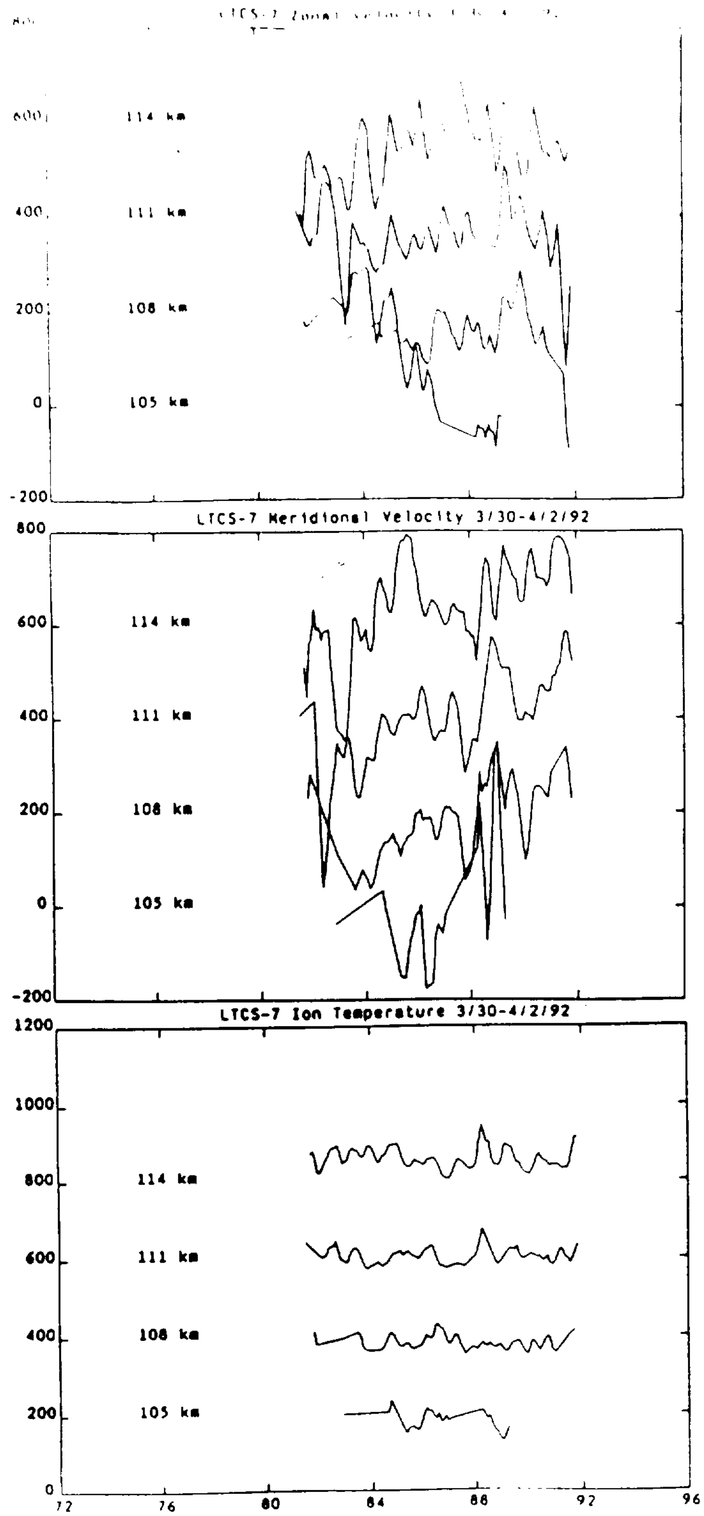

LTCS-7 Meridional Velocity 3/30-4/2/92
LTCS-7 Ion Temperature 3/30-4/2/92
114 km
111 km
108 km
105 km

FIGURE 6